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Abstract

Introduction Pelvic bone tumor resection is challenging due to complex geometry, limited visibility and restricted working space of the pelvis. Accurate resection in safe margin is required to reduce the risk of local recurrence. Computer-assisted preoperative planning and intraoperative navigation technologies have been developed for pelvic bone tumor surgeries, and clinical studies have already demonstrated the feasibility of achieving clinically adequate (tumor-free) resection margins [1]. Patient-specific instrumentation (PSI) technology has been developed and adapted to bone tumor surgery as a cheaper and less time-consuming alternative to intraoperative navigation. A recent experimental study has assessed an equivalent value-added of both PSI and navigation technologies in terms of the achieved surgical margins during simulated bone tumor resections of the pelvis [2]. The present study reports a series of 11 clinical cases of PSI-assisted bone tumor surgery within the pelvis, a...

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Accuracy of Patient-Specific Instrumentation for Bone Tumor Resection within the pelvis: 1st study of 11 patients

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Introduction

Pelvic bone tumor resection is challenging due to complex geometry, limited visibility and restricted working space of the pelvis. Accurate resection in safe margin is required to reduce the risk of local recurrence.
Computer-assisted preoperative planning and intraoperative navigation technologies have been developed for pelvic bone tumor surgeries, and clinical studies have already demonstrated the feasibility of achieving clinically adequate (tumor-free) resection margins [1].
Patient-specific instrumentation (PSI) technology has been developed and adapted to bone tumor surgery as a cheaper and less time-consuming alternative to intraoperative navigation. A recent experimental study has assessed an equivalent value-added of both PSI and navigation technologies in terms of the achieved surgical margins during simulated bone tumor resections of the pelvis [2].
The present study reports a series of 11 clinical cases of PSI-assisted bone tumor surgery within the pelvis, and assesses how accurately a preoperative resection strategy can be replicated intraoperatively with the PSI.

Materials and methods

The patient series consisted in 11 patients eligible for curative surgical resection of primary bone tumor of the pelvis. Eight patients had a bone sarcoma of iliac bone involving the acetabulum, two patients had a sacral tumor, and one patient had a chondrosarcoma of proximal femur with intra-articular hip extension.
For all cases, magnetic resonance imaging (MRI) and computerized tomography (CT) were acquired preoperatively for diagnosis. The tumor volume was first delineated on the MRI. The set of MRI and CT images were fused to produce 3D models of bone and tumor volume (Figure (a)). Resection planning consisted in desired cut planes positioned close to the boundary of the tumor (from 1 up to 6 planes) defining the desired bone cutting with a safe margin defined by the surgeon from 3 up to 15 mm.
PSI were designed in computer-aided design software according to the desired resection strategy and produced by additive manufacturing technology. PSI were designed to have bone-specific surfaces to fit in unique position on the bony structure of the patient. PSI were equipped with cylindric guides for 2-mm diameter Kirschner wires to be pinned on the bony structure and flat surfaces to materialize the desired cut planes. Intraoperatively, PSI were positioned freehand by the surgeon and fixed on the bone surface using the K-wires. Once the resection was achieved, both K-wires and PSI were taken off.

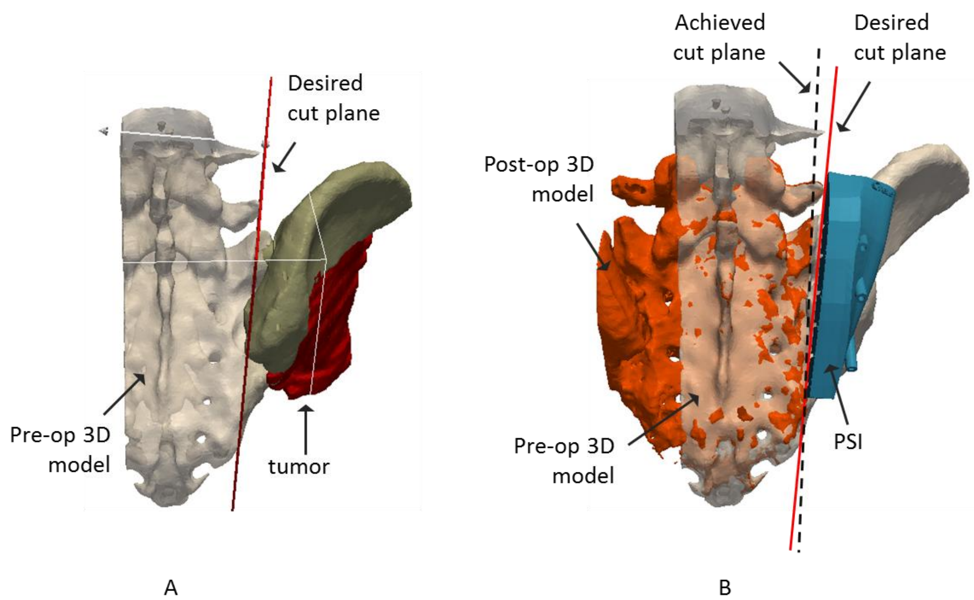

Figure (a) Preoperative planning for patient #2: one desired cut plane with a 6-mm desired resection margin. (b) Postoperative evaluation for patient #2: the achieved cut plane was identified and compared to the desired cut plane.

The standard surgical approach has been used for each patient. Dissection of soft tissue for bone exposure was in accordance with the routine technique. There was no additional bone exposure to position the PSI.

Histopathological analysis of the resected tumor specimens was performed to evaluate the safety of the achieved resection margins. Postoperative CT were acquired to assess the local control of the tumor.

3D bone models were reconstructed from the postoperative CT of the patient and registered with the corresponding preoperative bone model (Figure (b)). Two parameters were measured: achieved resection margin (RM) and location accuracy (L). RM was defined as the minimum distance (mm) between the achieved cut plane and the boundary of the tumor. Consequently, the error in the desired safe margin (ESM) was defined as the difference (mm) between RM and the desired safe margin. L was used in accordance with the ISO1101 standard [2] to evaluate accuracy between achieved and desired cut planes. L was defined as the maximum distance (mm) between the achieved cut plane and the desired cut plane.

Results

PSI were quick and easy to use with a positioning onto the bone surface in less than 5 minutes for all cases. The positioning of the PSI was considered unambiguous for all patients.

Histopathological analysis classified all achieved resection margins as R0 (tumor-free), except for two patients. Patient #8 had an urgent morcelized tumor because of severe bleeding, inevitably inducing R2 bone margins. Patient #5 had R1 resection because of soft tissues margins between 0 and 1 mm, although bone margins were classified R0.

The errors in safe margin averaged -0.8 mm (95% CI: -1.8 mm to 0.1 mm). The maximum positive error was 0.3 mm (patient #7), while the maximum negative error was -3.4 mm (patient #5).

The location accuracy of the achieved cut planes with respect to the desired cut planes averaged 2.5 mm (95% CI: 1.8 to 3.2 mm). The maximum inaccuracy was found for patient #5 with a difference of 4.4 mm between desired and achieved cut planes.

Discussion

Results in terms of the errors in safe margin ESM or the location accuracy L demonstrated how PSI enabled the surgeon to intraoperatively replicate the resection strategies with a very good cutting accuracy. These findings are consistent with the levels of bone-cutting accuracy already published in the literature on the clinical use of PSI and navigation technologies for bone tumor surgery. Ritacco et al. [1] reported a series of 28 navigation-assisted bone tumor resections with an average cutting error of 2.5 mm between planned and achieved resection planes. Khan et al. [3] also investigated bone-cutting accuracy in accordance to the ISO1101 standard and reported a 2-mm location accuracy during a PSI-assisted multiplanar resection on a cadaveric femur.
PSI technology described in this study achieved clear bone margins for all patients. Longer follow-up period is required but it appears that PSI has the potential to provide clinically acceptable margins.

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